Systems Practice in Engineering: Reflections on Doctoral Level Systems Supervision[1]

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1. Abstract

The Industrial Doctorate Centre (IDC) in Systems, a collaboration between the University of Bristol and the University of Bath, offers an Engineering Doctorate (EngD) in Systems Programme which is aimed at high-calibre engineers from graduate level to early/mid-career stage with the purpose of developing the systems-thinking capabilities of future leaders in industry. Research Engineers on this programme are based ~75% of their time in industry and focussed on a research project defined by their sponsoring company. This paper presents a personal reflection on the role of the systems supervisor on this programme with a focus on four areas of particular interest to the author i) alignment of industry needs and academic research, ii) developing an appreciation for the need for systems thinking, iii) navigating the systems literature, and iv) teaching research methods for doctoral research in systems. The purpose is to encourage and engage in debate on the development of systems practice in engineering.

2. Context and Purpose of Systems Supervision

The Industrial Doctorate Centre (IDC) in Systems[2], a collaboration between the University of Bristol and the University of Bath, offers an Engineering Doctorate (EngD) in Systems Programme which is aimed at high-calibre engineers from graduate level to early/mid-career stage with the purpose of developing the systems-thinking capabilities of future leaders in industry. Research Engineers on this programme are based ~75% of their time in industry and focussed on a research project defined by their sponsoring company. This project or programme of research

The research project is undertaken as a partnership between the collaborating company and the IDC in Systems. It can be a single project, or a series of projects, firmly based on a real industrial problem and having a significantly challenging and innovative engineering content. The company will normally identify the research topic, and will agree the project with the Research Engineer, the principal academic supervisor and the IDC in Systems. The principal academic supervisor on the EngD usually fulfils a similar role to a PhD supervisor in providing deep domain expertise in the area of need expressed by the collaborating industrial company.

In addition to the mandatory requirements of the Universities for second supervisors at the doctorate level to provide a second source of academic support there is the additional need from the EngD programme for the second supervisor to provide advice and guidance to the Research Engineer about systems thinking and systems research, especially when this is not available from the principal supervisor. As a consequence of the practice-led nature of the EngD in Systems it is evident that a Research Engineer is not the same as a ‘traditional’ PhD student and the systems supervisor needs to take this into account. It is also the case that the EngD in Systems is not what might be considered as a traditional programme in Systems Engineering; rather, as we have now presented to the International Council On Systems Engineering (INCOSE), it is systems thinking applied in an engineering context (Yearworth, Terry, Godfrey and Edwards, 2010).

This paper offers a personal reflection on this role and its purpose is to encourage and engage in debate on the development of systems practice in engineering. The focus is on four areas of particular

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[2] http://www.bristol.ac.uk/eng-systems-centre/

interest to the author i) developing an appreciation for the need for systems thinking, ii) alignment of industry needs and academic research, iii) navigating the systems literature, and iv) research methods for doctoral research in systems. Whilst other areas are of critical importance to the programme, such as skills development as systems practitioners in leading and managing change, these are not discussed here. This paper is derived from an internal working document produced by the author on the role of systems supervision and reflects the ongoing nature of the development of the programme.

Stylistically the paper is written in third person but the reader is enjoined to consider this a first person account. This, I believe, presents a cleaner text than one where almost every paragraph would otherwise begin "*I believe that…*" and descriptions of using specific texts, tools and techniques qualified with "*…by me*". It is also not intended that it is read as prescription, since this would rather defeat the pedagogy on the programme, but in the spirit of a debating position.

3. Appreciating the Need for Systems Thinking

The systems supervisor needs to be sensitive to the requirement that a systems, or holistic, approach has a crucial role to play in the analysis, design and intervention in complex socio-technical systems. Since the EngD in Systems is primarily focussed on industry needs arising from having to 'deal with' this socio-technical systems complexity specific projects are created in partnership between the IDC in Systems, the company, and the Research Engineer with an implicit understanding that a systems approach is an appropriate way of meeting needs.

We might characterise the need placed on systems supervisors as an ability to act on a 'systemic sensibility'. It does not matter how this systemic sensibility is manifested so long as it interacts with the Research Engineer in a way that supports their research journey on the programme.

A frequent need expressed by both companies and principal academic supervisors, not aware of the richness of the systems thinking intellectual landscape, is a succinct and pithy answer to the question "*what is systems thinking?*" The following quotations have been used on occasions in answer to this, and also in research seminars within the Faculty of Engineering and with Research Engineers on the programme. They also represent something of a 'local' view representing opinions of people with some connection to the programme.

> "*Systems thinking provides a rigorous way of integrating: people, purpose, process and performance and i) relating systems to their environment, ii) understanding complex problem situations, iii) maximising the outcomes achieved, iv) avoiding or minimising the impact of unintended consequences, v) aligning teams, disciplines, specialisms and interest groups, and vi) managing uncertainty, risk and opportunity. It is founded on three key ideas i) layers, ii) loops, and iii) new process. The phrase 'new process' is used to identify a holistic view of process, which describes natural, people and physical processes in a consistent way. This helps to integrate all types of system. It also helps to align stakeholders to purpose and reduce a substantial source of complexity.*"
> (Godfrey and Woodcock, 2010)
>
> "*Systems thinking is…a way of tackling complex problems. It complements scientific thinking by addressing holism, emergence and intentionality (Stakeholders and the "Human in the system")*"
> (Sillitto, 2009)
>
> "*Viewing situations holistically, as opposed to reductionistically (sic), as a set of diverse interacting elements within an environment. Recognising that the relationships or interactions between elements are more important than the elements themselves in determining the behaviour of the system. Recognising a hierarchy of levels of systems and the consequent ideas of properties emerging at different levels, and mutual causality both within and between levels. Accepting, especially in social systems, that people will act in accordance with differing purposes or rationalities.*"
> (Mingers and White, 2010)

When an industrial supervisor or principal academic supervisor asks for a book to read this places a burden on the systems supervisor to choose an appropriate entry point to the systems literature. This choice is likely to colour opinion of systems thinking depending on degree of alignment with worldview and current problem situation. Based on using books from the wider reading list for the

Research Engineers the following have been suggested on occasions depending on rough characterisation of worldview:

- a model-driven and simulation based approach (Chaturvedi, 2009),
- a broad systems engineering approach (Hitchins, 2007),
- a set of heuristic-based systems practices and a new view of process (Blockley and Godfrey, 2000),
- a critical systems practice view (Jackson, 2000, Jackson, 2003),
- Checkland's "*process of systemic enquiry*" (Checkland, 1999, Checkland and Scholes, 1999, Checkland and Poulter, 2006).

These have been ordered roughly in order of 'accessibility' to an engineering audience, whether academic or industry. All provide different entry points into systems thinking and systems practice but what is essential is that a perspective is introduced that includes the social in socio-technical complexity.

4. Alignment Between Industry Needs and Academic Research

During the induction week onto the EngD in System programme and in the introduction to research methods teaching we have used a diagram like Figure 1 to show our area of focus.

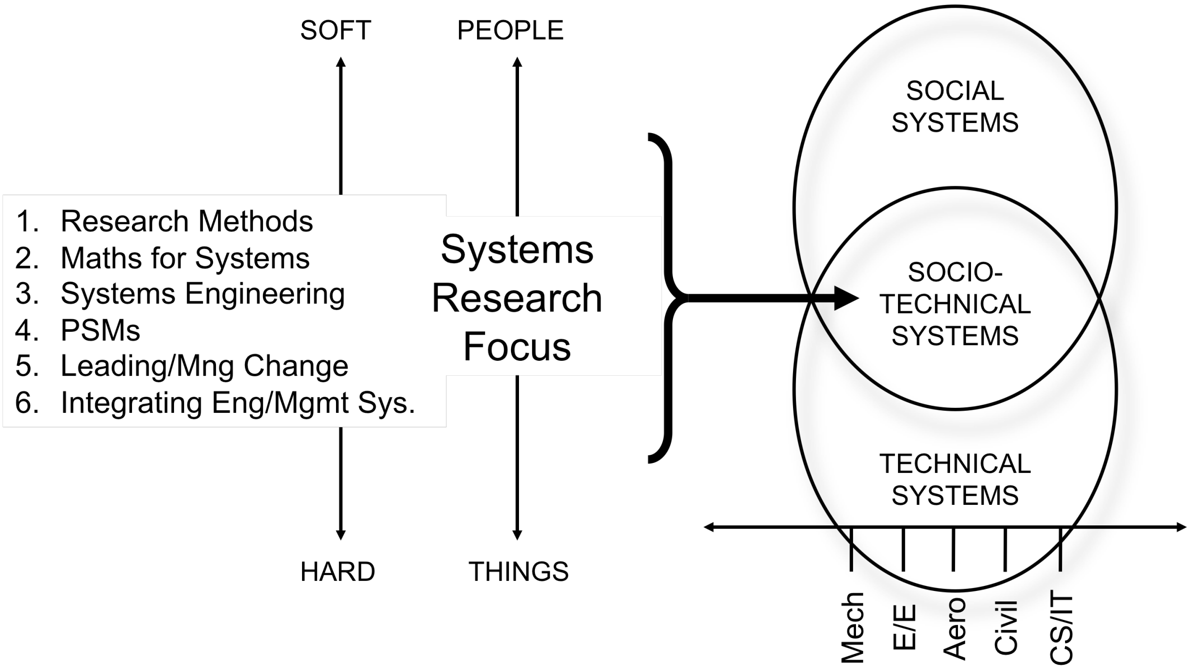

Figure 1. Research at the interface between technical (physical) and social systems. The numbered items represent core elements from the taught components of the EngD in Systems programme. Derived from (Yearworth, Edwards and Rosenberg, 2011).

Given the unique nature of the programme and its professed focus on industry needs-driven, complex socio-technical problems it is important that the systems supervisor has an appropriate input into the question of system boundary that the Research Engineer and the company are working with for their project. In practice this is not a single decision but an ongoing process of examination for the duration of the research. At progress review meetings projects may be found to be missing the potential for greater impact by a system boundary too narrowly conceived in the technical system. The systems supervisor then needs to provide the stimulus to explore the question. Whilst this could involve detailed theoretical consideration linked to methodology selection (Ulrich, 2003, Ormerod, 1997), it is enough for the Systems Supervisor to constantly bring the question to the table. Experience has shown that maintaining focus on the socio-technical whilst simultaneously maintaining grounding in engineering competence requires vigilance.

Ideally this question is reviewed at project definition phase in early discussions with the industrial partner. Clearly this represents an ideal, we embark on projects well aligned with the focus and capabilities of the IDC in Systems and the systems research agenda. Reviewing system boundary can be a rewarding experience, it frequently offers a rather eye-opening experience to our industrial partners and the opportunity for a project to deliver impact beyond its original conception.

There is growing awareness of the need to improve the quality of research in systems engineering. (Brown, 2009) makes quite a compelling case and Research Engineers are made aware of this paper. The INCOSE Systems Engineering Annual State of the Nation (SEASON) report (Sillitto, 2009) makes a similar case. In its Executive Summary it states "*There is a need to improve the standing, recognition and reputation of Systems Engineering in academia*", and in its recommended key axes for development says "*Improve the Academic profile of Systems Engineering and Systems Thinking by setting out an agreed, intellectually rigorous foundation for the discipline*". Happily, or otherwise depending on viewpoint, this aligns well with drivers from the Research Excellence Framework (REF)[3] in the UK. The systems supervisor has a crucial role to play here.

Since systems thinking and systems practice "*continuously create each other*" (Checkland, 2010), systems research is thus essentially practice led, which means that it is likely that the Research Engineer will be directed by their principal academic supervisor to the literature of the domain of their project, both for literature review, but also as a place to publish too. The systems supervisor has to be sensitive to this whilst attempting to try and abstract away from the application to developing a contribution to knowledge of what systems practice in engineering actually means. Whilst a Research Engineer is likely to start publishing about the *application* of systems methods/thinking/techniques to their problem situation, greater academic contribution can be made by reflection or critique of the methods/thinking/techniques so that they too can develop in engineering. This point has been made by a number of other authors (Brown, 2009, Ferris, Cook and Honour, 2005, Valerdi and Davidz, 2009).

5. Navigating the Systems Literature

Navigating the breadth of systems literature is a huge task. It would help tremendously if the systems supervisor could guide the Research Engineer's reading through the diverse landscape that is the systems literature and to do this in a way that doesn't overwhelm. Whilst reading is guided through the taught part of the programme the systems supervisor really needs to be able to match the Research Engineer's research project needs with appropriate sources. The following textbooks have been recommended at various points (Ackoff and Emery, 1972, Burrell and Morgan, 1979, Flood, 1999, Jackson, 2000, Jackson, 2003, Reynolds and Holwell, 2010, Ramage and Shipp, 2009, Bertalanffy, 1973, Burns, 2007, Hitchins, 2007, Checkland, 1999, Vennix, 1999, Meadows, 2008, Sterman, 2000, Senge, 1990, Blockley and Godfrey, 2000, Fuller, 2006, Magee, 1973, Chaturvedi, 2009, Checkland and Poulter, 2006, Checkland and Scholes, 1999). The journal and conference literature is even more of a challenge and again it would help if the systems supervisor could direct reading to key *systems* journals and conferences for their project. As part of the integration between Research Methods and Advanced Systems teaching a critical reading exercise has been introduced based around a set of papers that lead the Research Engineer from the process of researching systems to a practice of intervention (Brown, 2009, Ferris, Cook and Honour, 2005, Jackson, 2006, Lane, 1999, Lorenz, 2009, Midgley, 2003, Mingers and White, 2010, Richardson and Kramer, 2006, Sterman, 2002, Valerdi and Davidz, 2009, Elliott, 2006), and prepared to contribute to its development.

Despite attempts to avoid prescription on the programme reading lists by their very nature direct reading. Also, much of the systems thinking literature has emerged from the management domain and whilst it is possible to learn across into engineering it would be useful if there was a canon which could support the notion of systems practice in engineering. Both (Blockley and Godfrey, 2000) and (Hitchins, 2007) provide a useful foundation.

[3] http://www.hefce.ac.uk/research/ref/

6. Research Methods

There is a need to achieve better integration between the methods used to *research* complex socio-technical systems and the problem structuring methods (PSMs) used to *intervene* in those systems. The development of research methods teaching on the programme is described in (Yearworth, Edwards and Rosenberg, 2011), and a case study for integration in (Edwards and Yearworth, 2011). Research methods teaching on the programme challenge the Research Engineer with a strong emphasis on the phenomenological paradigm by introducing research approaches and strategies from the social sciences. The systems supervisor needs to support the Research Engineer through this. The following extract from (Yearworth, Edwards and Rosenberg, 2011) illustrates the challenge to the supervisory team:

> *"Significantly, most Research Engineers admit to a rather superficial understanding of their 'systems' and purposes of their project at the time of undertaking the initial research methods training. However, all express a strong desire to more fully explore their systems and problem situations as a key first step. Several indicate how the training has given them an entirely different perspective on how to make a start on their work.*
>
> *Overall, Research Engineers' reflective logs indicate a very intense learning experience, which shakes them up to some extent and fundamentally challenges their existing worldview as engineers in relation to real world systems and systems research.*
>
> *Categories emerging from the above analysis fall into two broad groups*
> 1. *Complexity of the problem, stakeholders and system boundary, and the alignment of research questions with the industrial problem being solved, and*
> 2. *Dealing with countercultural and counterintuitive ideas from phenomenological and mixed research paradigms.*
>
> *The first of these might be considered the 'bread and butter' of systems research. The second emerging category is more problematic and can be broken down into a set of concerns as follows:*
> - a. *Rigour and validity of phenomenological research approaches e.g. the perceived weakness of induction and unreliability of qualitative data analysis*
> - b. *Dealing with Action Research and its links with system intervention approaches*
> - c. *Discomfort of having to justify phenomenology and qualitative research methods in an engineering company*
> - d. *Social skills necessary to conduct qualitative research and apply appropriate techniques e.g. grounded theory.*
>
> *The range and scope of projects represented on the programme means that a Research Engineers may identify with any one or more than one of these categories and issues. It is the concerns about phenomenological research in an engineering context that generates the greatest supervisory load. Also, the apparent lack of integration so far in the current literature between generic research methodologies and broader systems intervention approaches provides a challenge in order for Research Engineers to demonstrate intellectual and methodological rigour at all levels of their work."*

As the balance of the Research Engineer's project moves towards intervention, from merely researching, then the explicit acknowledgement of conducting Action Research is crucial and the systems supervisor must be very supportive. This is especially so when the initial basis for intervention arises from phenomenological research and the concomitant discomfort at having to justify these methods in a commercial engineering environment.

7. Conclusions

The author's four focus areas of systems supervision presented here represent just the beginning of the debate about this role in the context of systems practice in engineering. Few conclusions can be drawn as the programme is only now producing its first graduates and the role of systems supervision will be critically examined as part of the Systems Practice in Engineering (SPiE) project that has started recently. Of the four areas presented it is getting the right alignment between meeting industry needs – which has concomitant need to demonstrably deliver impact – and the focus within the University on doing well in the REF that presents a significant challenge. Checkland comments on the distorting impact, "*baleful influence*", this measurement process has on systems practice (Checkland, 2006), and it is entirely possible that this exacerbated in engineering by the narrow technical focus of the discipline-based units of assessment. The systems supervisor is at the heart of achieving this balance.

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